Safe Autonomous Flight Environment for the Notional "First/Last 50 Feet" (SAFE50) Project

Toward UAS Operations in High-Density Low-Altitude Urban Environments

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UAS Operations in High-Density Low-Altitude Urban Environments

Unmanned Aircraft Systems (UAS) Traffic Management (UTM) concepts are advancing toward flight over populated regions.

Significant technical challenges are imposed by these environments that makes traffic management difficult, particularly for low-altitude flight in high-density urban environments.

Studies anticipate high demand and economic growth potential in this market.

How do you facilitate routine, safe, and fair access to this high-demand airspace?

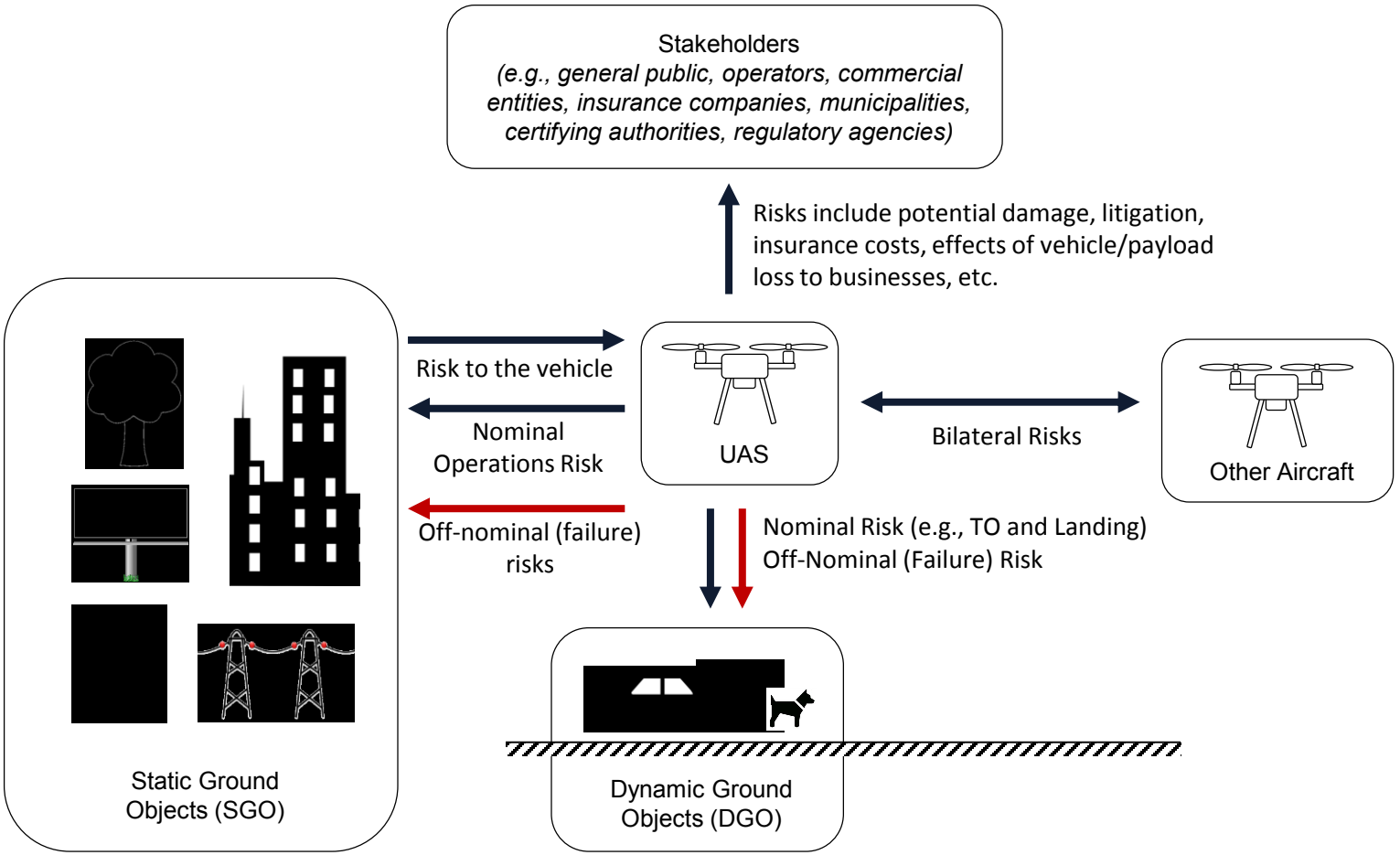
Motivating Scenarios

Safe and Regular Access for sUAS to High-Density Low-Altitude Urban Airspaces

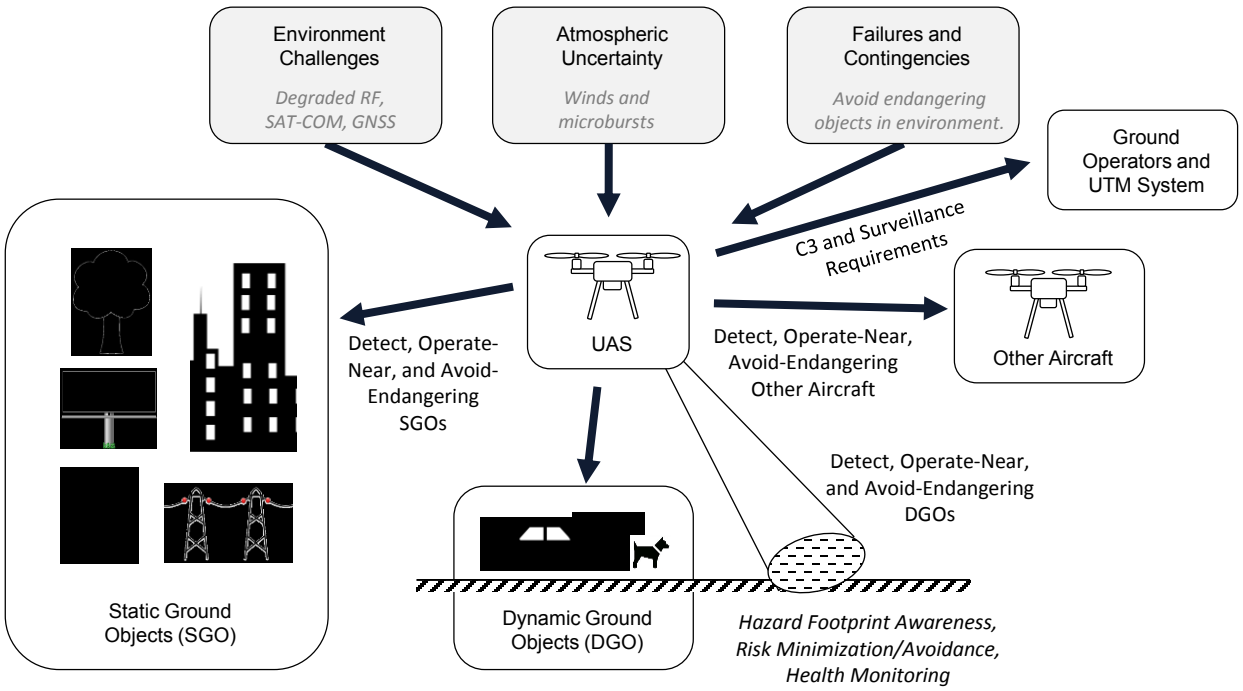
Challenges

- Low-altitude autonomous flight is inherently higher risk
- Mixed-use airspace
- Highly-constrained spaces within urban canyons
- High-density environment
  - Other manned and unmanned airborne vehicles
  - Flight near and above high-valued assets
  - Cluttered wireless environment
- Hazardous ambient conditions, precipitation, and adverse winds
- Dynamic environment with significant uncertainty
- Limited size, weight, and power (SWaP)
- Regulations must establish acceptable risk posture and safety margins
- Separation assurance (SA) and collision avoidance (CA) are difficult services to provide

Consideration of Risks



SAFE50 Vehicle Autonomy Requirements



Challenges for UAS in Urban Environments

- Low reliability of current small UAS (high failure rates)
- Significant variability in vehicle systems and technologies on the market
- Limitations in current guidance, navigation, and control technologies
- Inability to see-and-avoid
- Limited onboard autonomy
- Limited understanding of vehicle behavior and dynamics in this environ.
- Limited onboard failure accommodation
- Insufficient communications technologies for urban environments
  - Vehicle to ground, vehicle to vehicle, satellite coms, GNSS derived PNT
- Surveillance technologies are difficult to apply to this environment
- There is no common set of vehicle-level and systems-level requirements yet available for UAS in low-altitude urban flight.

Vehicle Autonomy

- 'Autonomy' broadly generalized encompasses anything that allows systems to sense, think, communicate, and react with less human intervention.

- Research literature in UAS and vehicle autonomy is extensive, covering a broad range of disciplines and techniques, and touching on all of the challenges and limitations we have identified to some degree.

- Substantial levels of private/commercial R&D investments are targeted toward advancing vehicle autonomy technology.

- While the technology is rapidly advancing, there are still severe limitations in commercially available off-the-shelf (COTS) technologies and UAS vehicle systems.

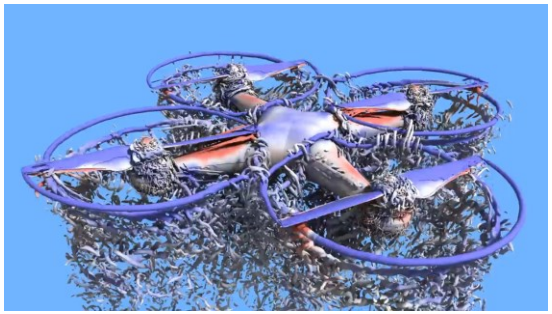
SAFE50 Project Goals and Approach

- Conduct an advanced study focusing on onboard vehicle-centric autonomy requirements that will allow safe, autonomous and routine sUAS access to high-density low-altitude urban environments, and integrates into the emerging UTM framework.
- Advanced study will guide the next phase for a larger systems-level study
- Develop feasible point-designs for system-level and vehicle-level concept
- Develop prototypes and demonstrate feasibility of point-design
- Assemble and develop analysis tools
  - Validated high-fidelity sims, software/hardware prototypes, flight vehicles
- Analyze effectiveness of the point-design in addressing technical challenges
- Leverage UTM partnerships to track emerging trends, technologies, gaps
- Work with academia and industry towards enabling urban area access
  - Peer-reviewed and competed awards, encouraging academic/commercial partnerships, see announcements at https://nspires.nasaprs.com/

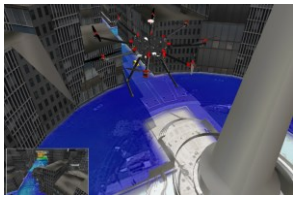
Research Highlights

Dynamics Modeling and Simulation

Using computational fluid dynamics and wind tunnel experiments to created higher-fidelity and validated flight dynamics models.



Credit: Tim Sandstrom, NASA Ames Research Center



Simulation Models

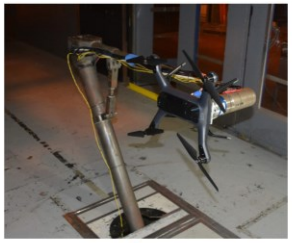


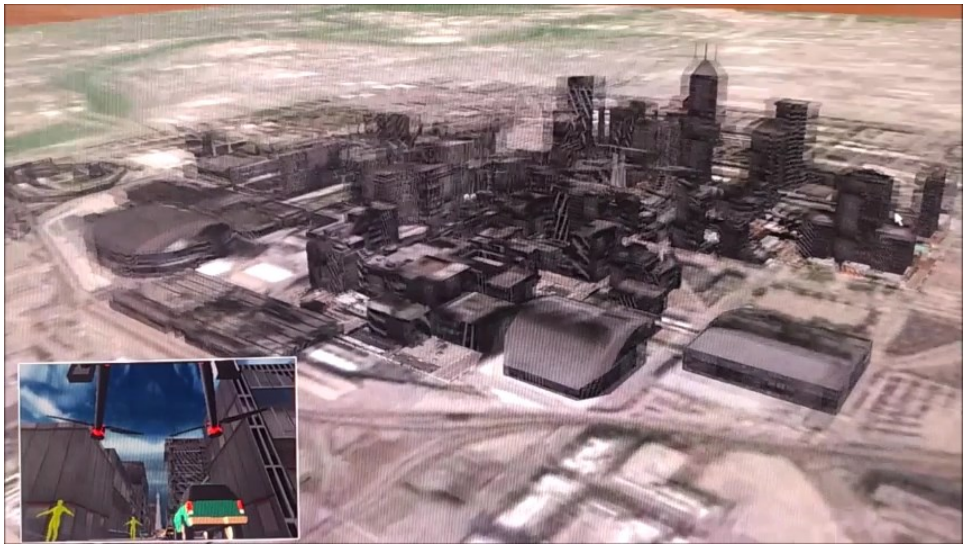
Figure 2. 3D Robotics SOLO.

Figure 5. Drone America DAx8.

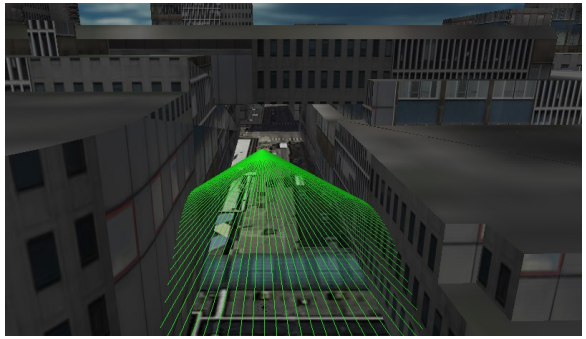
Figure 3. DJI Phantom 3 Advanced.

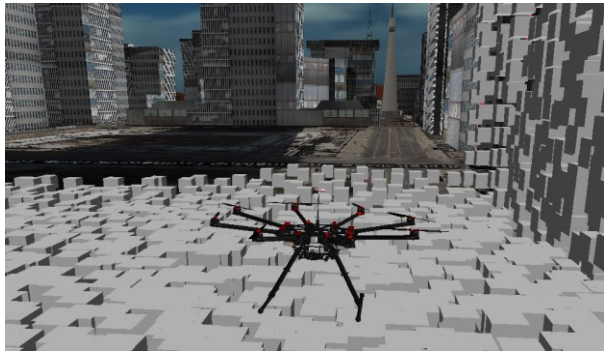
Figure 6. SUI Endurance.

Vehicle Testing in 7x10 ft Wind Tunnel
Courtesy of Carl Russel, UTM, NASA Ames Research Center



Autonomous Sensor Fusion, Environment Mapping and Hazard Characterization





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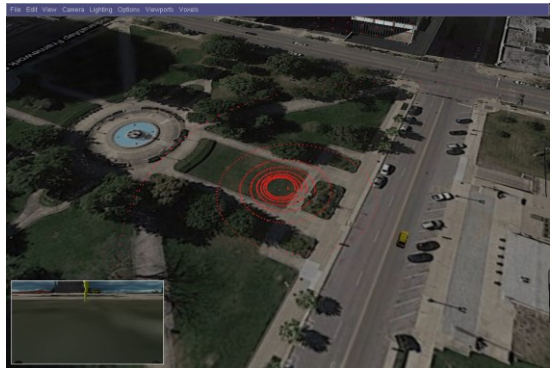
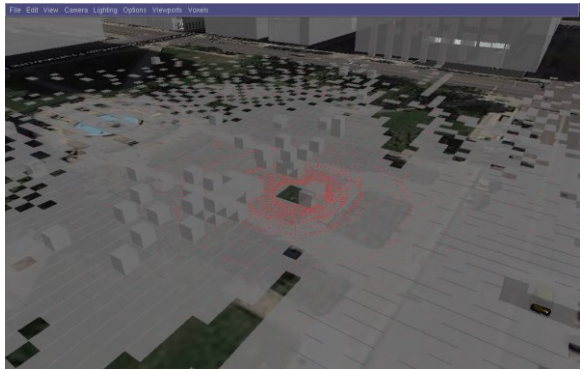
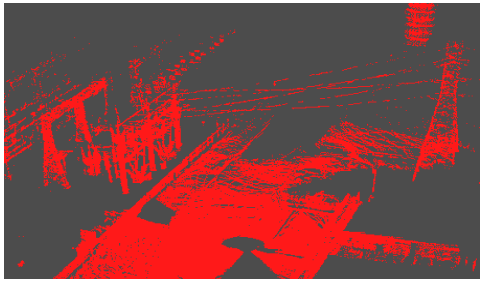
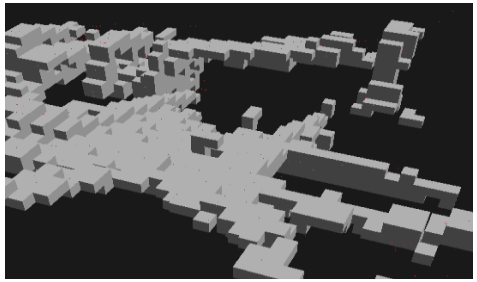
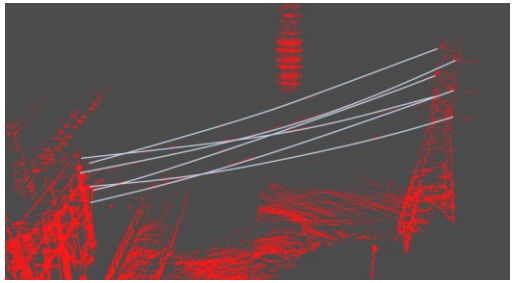




Environment Mapping Evaluations (LiDAR and Vision)



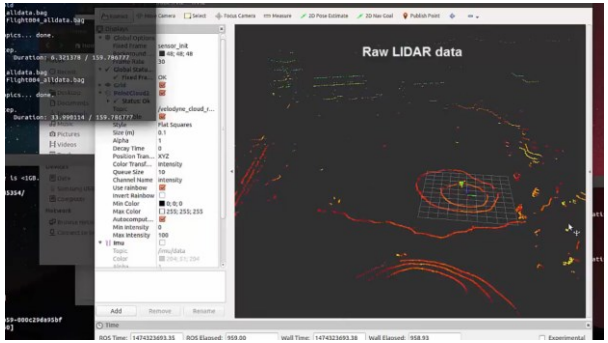


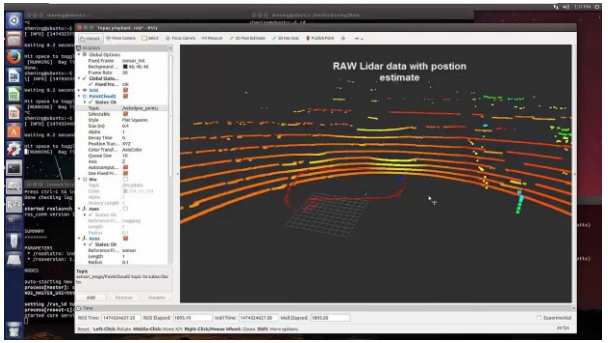


Powerline Identification and Reconstruction. Raw LiDAR point clouds (left), voxel processing (middle), reconstructed powerlines at 75m (right).

GNSS/GPS Denied and Degraded Environments

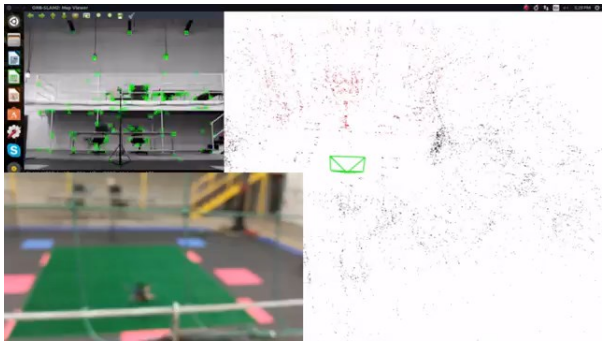
Investigating integrated GNSS, LiDAR and vision for robust simultaneous localization and mapping (SLAM)





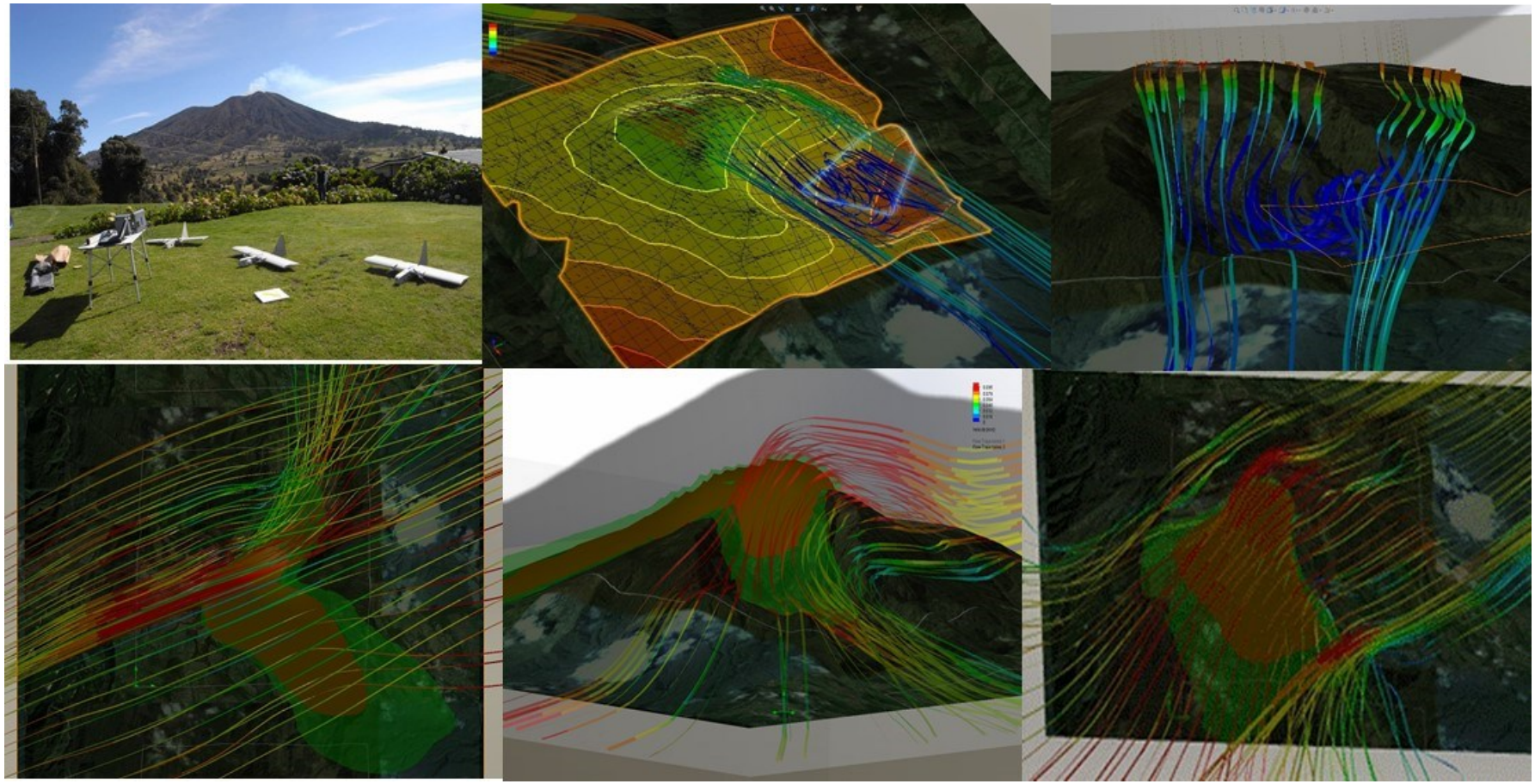
LiDAR SLAM in NASA RoverScape Test Facility (collaboration with Near-Earth Autonomy, Inc.)

LiDAR SLAM in NASA Disaster Assistance and Rescue Team (DART) Training Facility



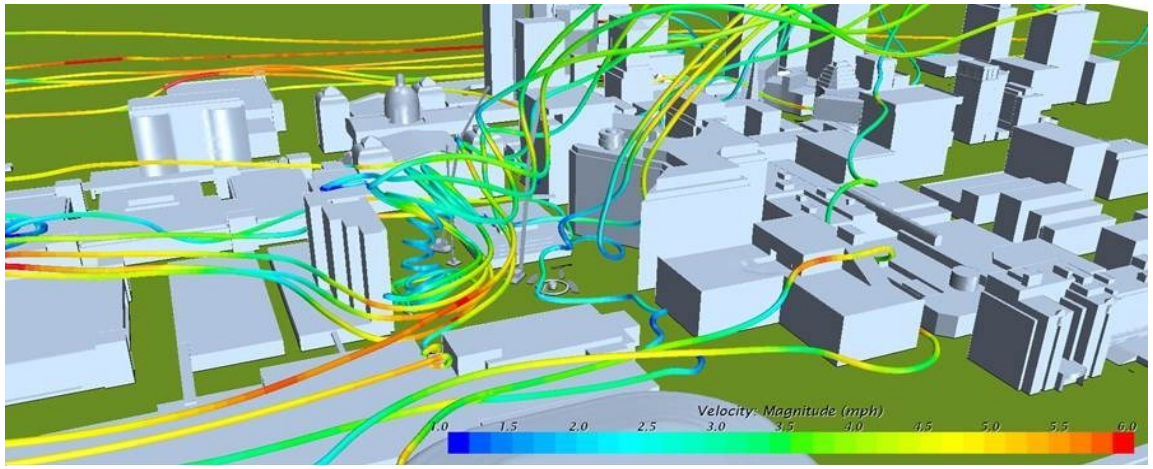
Vision-Based SLAM –
NASA NUARC Test Facility

Natural Terrain Multi-Species Wind Modeling and Estimation under Uncertainty

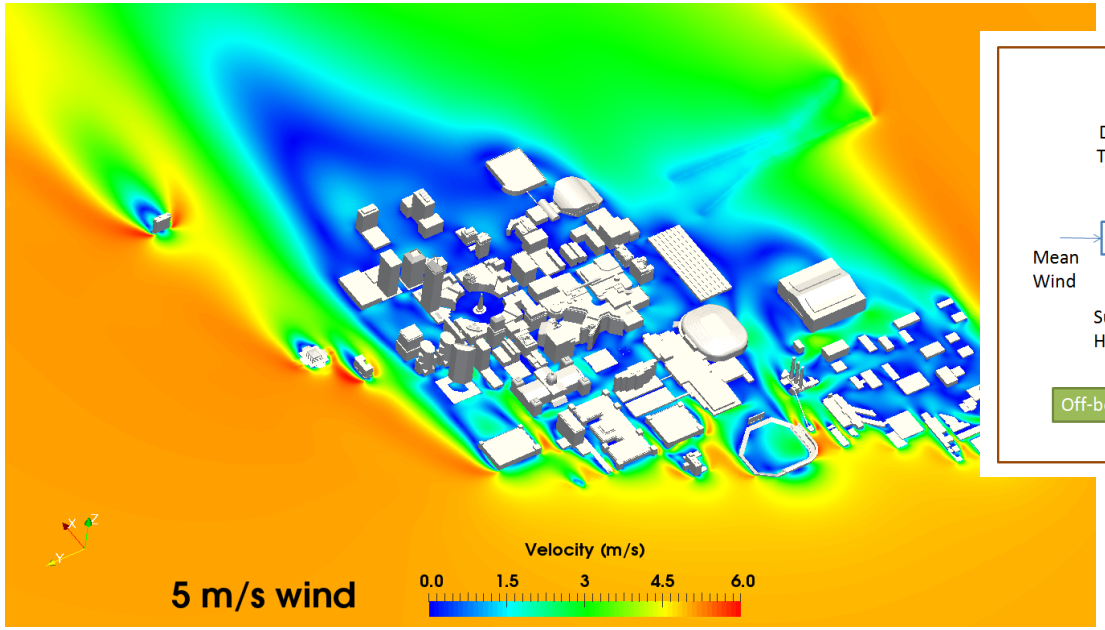


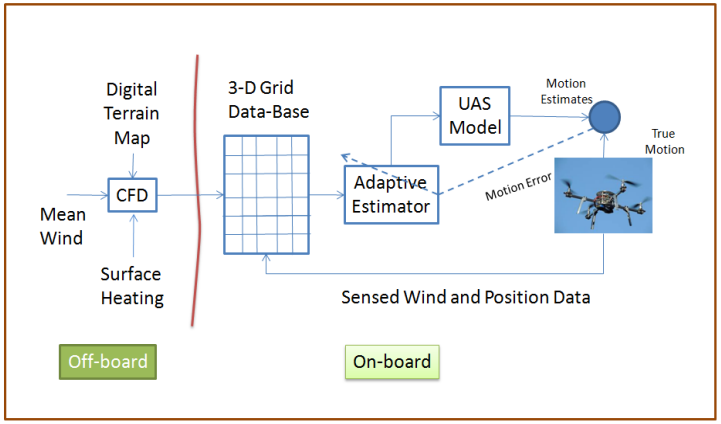
Swarming Dragon-Eye Volcanic Plume Monitoring Project -
CFD study investigated SO2, CO2, and water vapor plume transport at anticipated emission rates over the Turrialba Volcano in Costa Rica.

Urban Environment Wind Uncertainties

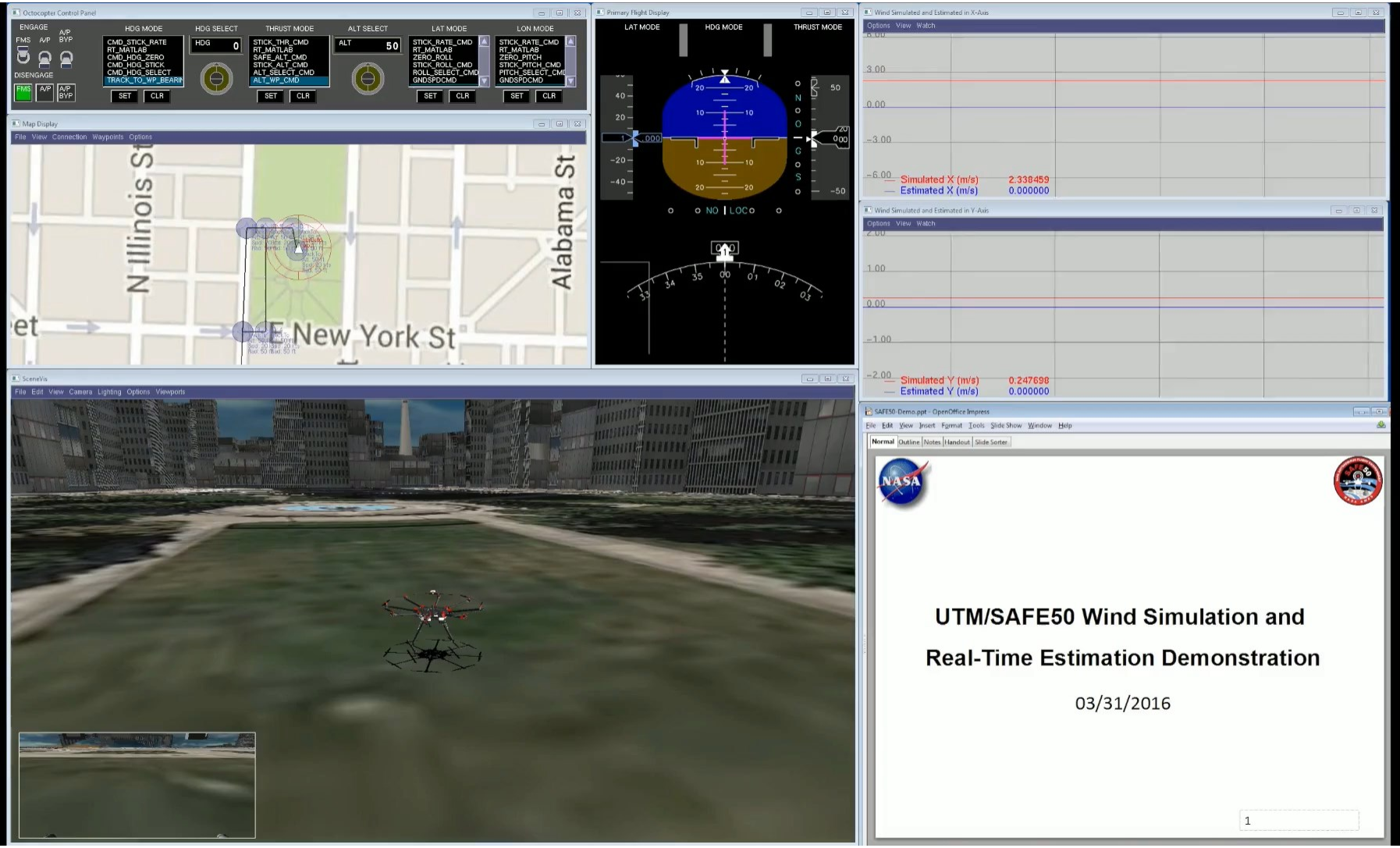


Urban Architecture and CFD Simulation of Wind Profiles.

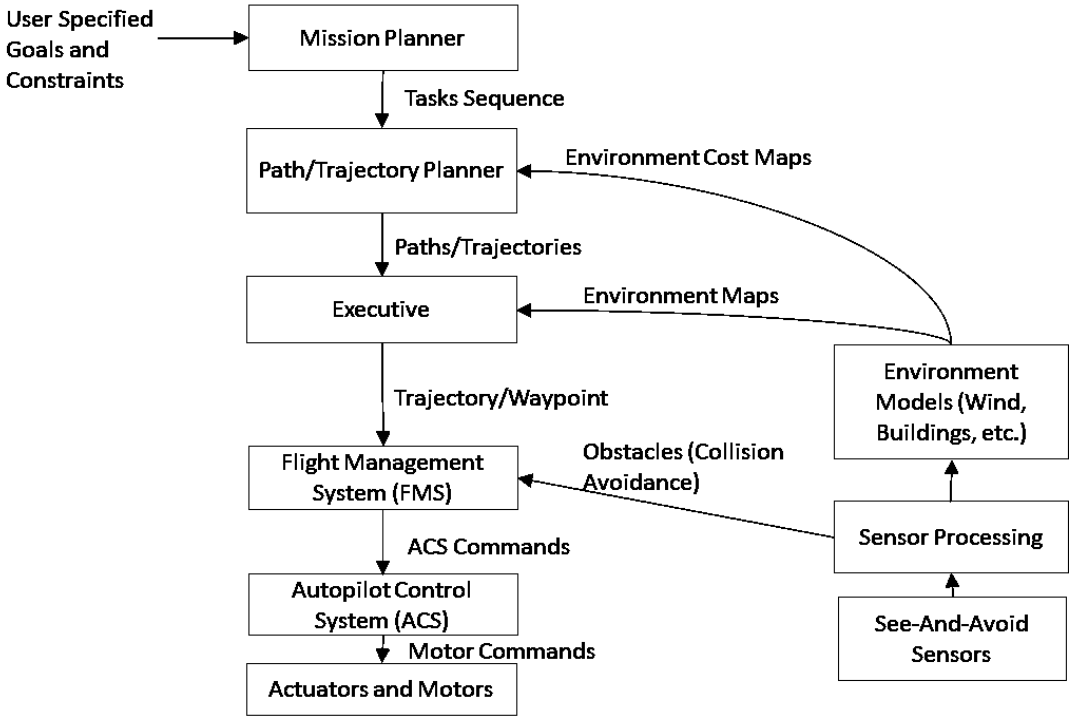




UrbanScape Wind Uncertainties

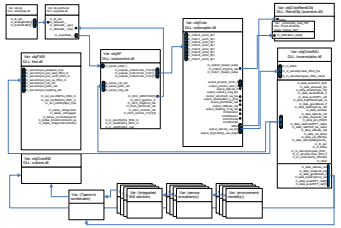


Autonomy Payload Architecture and Prototyping

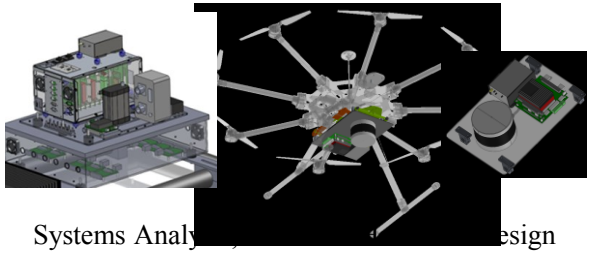


Autonomy Architecture

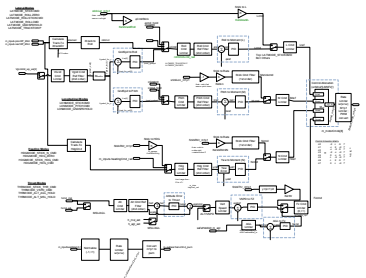
Flight Testing - NASA SAFE50 and UTM Flight Test - August 2015



Real-Time Embedded Software Architecture



Systems Analy esign



Experimental Multicopter Flight Management and Flight Control System

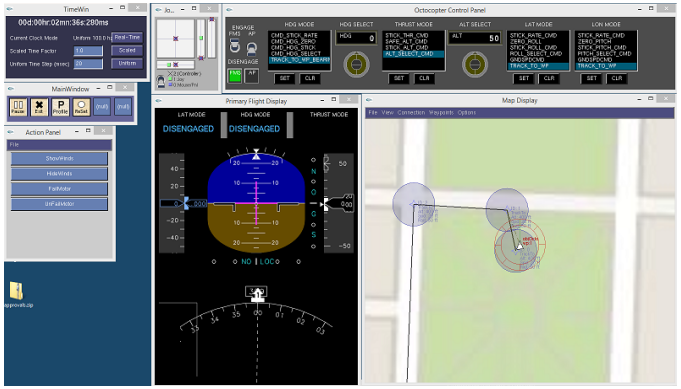
Integrated Payload/Vehicle Test Platform

Flight System Interfaces and Ground Control System Development

Hardware-In-The-Loop Vehicle Simulation Configuration

Ground Control Stations

Multi-Vehicle Simulation Integration - Airspace Operations Laboratory (AOL) NASA Ames Research Center



Custom GCS Control Interfaces

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